Chapter 2. Methods

This chapter describes the methods that were used to quantify the extent of historical riparian habitats and adjacent land uses. First, the criteria that were used to establish the limits of the study area are described. Next, the methods used to determine the extent of prehistoric riparian habitat and changes in the historical extent of riparian habitat since 1937 are documented.

Study Area Boundary

The study area boundary was chosen to include current and historical riparian vegetation and adjacent land uses along the mainstem of the San Joaquin River between Friant Dam and the Merced River. Because of the extensive human modification of the floodplain in most of the study area, it was difficult to determine the natural floodplain of the mainstem of the river. Instead, a set of rules was devised (based on the 1978 situation) to ensure that riparian habitat associated with the mainstem and adjacent land uses was included despite the complexity of conditions in the study area. The rules devised are as follows:

- When a clear escarpment or levee that confined the river was present, the boundary was set at 1,000 feet beyond the escarpment or levee (e.g., the upper portion of Reach 1 and most of Reaches 3 and 4).

- When no levee or escarpment was present but the outer boundary of riparian vegetation associated with the mainstem was clear, the boundary was set at 1,000 feet beyond the outer limit of the riparian vegetation (e.g., portions of Reaches 1 and 2).

- When no levee, escarpment, or clear, discrete outer boundary of riparian vegetation was present, but riparian vegetation extended more or less continuously from the mainstem to adjacent sloughs or side channels, the boundary was set at 2,000 feet from the center line of the main channel of the San Joaquin River (e.g., portions of Reach 5).

Mapping Methods

Soil Survey Interpretation

The interpretation of the soil survey provides a quantitative estimate of the area that in prehistoric times had the potential to support riparian vegetation, based on landscape position and soil attributes. However, because the hydrological and biological parameters are unknown, the interpretation overestimates the potential extent of prehistoric riparian vegetation that may have occurred in discontinuous patches or linear bands within only a portion of suitable soil types.

Landscape position and soil characteristics were the basic attributes used to infer the potential extent of prehistoric riparian habitat. Landscape position includes, for example, floodplain, basin, basin rim, and alluvial fan landforms. Soil characteristics include texture, drainage class, origin of parent material, and degree of soil profile development. For the study area, the soil mapping units listed in Appendix A were included to represent the potential extent of historic riparian vegetation. These soil mapping units correlate to low and high floodplains and, at the upper limit of the floodplain, recent or young terrace fans. These soil mapping units occur mostly on recently deposited alluvium.

This approach is similar to that of Roberts et al. (1977), who used reconnaissance soil surveys of the Sacramento and San Joaquin Valleys published before 1920 (Holmes et al. 1915 and Nelson et al. 1918) to map the potential original extent of riparian woodland below the 300-foot contour from Redding to the Merced River. The present study relied on modern soil surveys because they represent a refinement of the early reconnaissance surveys and show soils at a higher level of resolution.

Appendix A also includes soil mapping units that occur as small soil inclusions or stringers within the riparian landscape that, based on their landscape position within the floodplain, may have supported riparian vegetation. Additionally, several soil mapping units that contain a saline or alkaline modifying suffix (e.g., Chino loam, saline-alkali or Merced clay loam, strongly saline, channeled, 0-3% slopes) were mapped as riparian soils because, based on interpretation of aerial photographs from 1937, 1950, and 1957, well-developed riparian vegetation was present. Soil survey descriptions also state that portions of these soil mapping units may not be constrained by salt or alkali, which may explain the presence of the riparian vegetation.

Detailed modern soil surveys were available for all portions of the study area. Because the surveys were prepared on an area-by-area or county-by-county basis and in different years, inconsistencies in soil mapping conventions occurred at the boundaries of the soil surveys. For example, in the Mendota and Firebaugh area, Columbia soils were mapped on both sides of the San Joaquin River by the Madera Area California Soil Survey (Soil Conservation Service 1962) and Mendota Area California Soil Survey (Soil Conservation Service 1956); however, because the Mendota Area California Soil Survey is being superseded by the Fresno County Soil Survey (Western Part) (Natural Resources Conservation Service in prep.), soils on the west bank of the San Joaquin River, which

were once mapped as Columbia series soils, will now be mapped as Elnido, Bisgani, or Palazzo series. The Natural Resources Conservation Service will be preparing a unified soil survey for the entire state that will eliminate such inconsistencies, but the unified soil survey will not be completed for several years (Arroeus pers. comm.).

The historical written descriptions of pristine vegetation along the San Joaquin River above the confluence with the Merced River are anecdotal in nature and refer mostly to extensive areas of tule marsh, with locally abundant groves of riparian forest (Fox pers. comm.). The general character of the historical riparian vegetation was assumed to be similar to existing remnant patches of well-developed riparian vegetation. Thompson (1961) described the major streams of the Sacramento Valley as bordered by well-developed riparian forests and woodlands occurring on the coarse alluvium of natural levees and river terrace deposits. Sub-irrigation, fertile alluvial loam soils, and relative freedom from surface waterlogging and fire were major factors contributing to their presence (Thompson 1961). Thompson correlated remnant riparian patches with historical evidence contained in diary accounts of early Central Valley explorers to conclude that the remnant patches did indeed reflect the historic conditions.

By applying Thompson's assumptions to the San Joaquin River, the low and high floodplains probably were vegetated by a winter deciduous broadleafed riparian forest characterized by Fremont cottonwood, several species of willow, sycamore, box elder, Oregon ash, valley oak, buttonwillow, wild grape, California blackberry, and clematis. This assumption is validated by recent field observations and limited historical references. Nelson et al. (1918) described native vegetation occurring on Hanford series soils (the only recently deposited alluvial soil mapped along the San Joaquin River at that time) as including a moderate to heavy growth of willows, native vines, and cottonwoods that added considerable cost to land clearing for agricultural conversion. The California Debris Commission Map of the San Joaquin River from Herndon to the Merced River (U.S. Army Corps of Engineers 1917) shows extensive areas of brush in the riparian zone that most likely represent cottonwood and willow vegetation associations. Hall (1878) mapped a channel island near present-day Highway 99 at the railroad crossing as covered by dense brush and willows.

While valley oak was not a dominant tree in the active floodplain, it probably was the dominant tree of young terrace fans. Other riparian trees, shrubs, or vines that are less water-table dependent, including sycamore, Oregon ash, box elder, Mexican elderberry, blackberry, poison oak, grape, clematis, and wild rose, probably were also present. A description of the vegetation along the Kings River (which contains similar recently deposited alluvial soils) written by Hall (1880) can be assumed to describe vegetation similar to that present along the historical San Joaquin River. Hall described the Kings River riparian vegetation as "thick growth of valuable timber composed principally of oak, with some cottonwood and willows, which latter are found immediately along the riverbanks while the former extends out on the plains for several miles each side of the river. The soil within the timber belt is rich and productive upon compare. This extensive belt of woodland forms one of the most prominent and anomalous features upon the face of the country".

In the river reach below Firebaugh, the floodplain contains a narrow band of riparian soils that form a complex association with basin soils (historic tule marsh soils). The mapping of riparian soils was mostly limited to the recently deposited alluvial soils occurring next to the river, even though the same soils may also occur away from the river but are separated by basin clays or clay loams. Minor areas of clay loam, however, were included within the riparian soil category if they occurred between a major slough (e.g., Pick Anderson Slough) and the San Joaquin River. The vegetation in the river reach below Firebaugh probably was a complex of cottonwood, willows, buttonwillow, and tules, with the woody species being limited to the coarse-textured soils of higher ground, natural levees, or around the margins of oxbow lakes. Hall's *Topographic and Irrigation Map of the San Joaquin Valley* (1886) shows swamp and overflowed lands up to 6 miles wide in this area. Township plat surveys (circa 1855) map the areas as "overflowed willow swamp or tule swamp". A local newspaper, the *San Joaquin Democrat*, reported tules as far as the eye could see in an article from the 1860s (McKown pers. comm.).

Aerial Photograph Interpretation

Photographic Materials

Historical aerial photographs were used to identify land cover signatures. The years studied were chosen to be within the following four periods:

- between 1880s and 1944: prior to the operation of Friant Dam;
- between 1944 and 1967: a drought period;
- between 1967 and 1983: a period of floods; and
- between 1983 and 1993: a drought period.

Extensive research was conducted to locate historical aerial photographs at government agencies, libraries, and universities. Although many sources for aerial photographs of the San Joaquin River Basin (Appendix B) were found, in most cases, complete coverage of the entire study area was unavailable for a particular year. Table 3 lists the photographs that were used for this project. Differences in scale and quality of the photographs affected quality of the data.

Ideally, false-color infrared photographs should be used for identification of vegetation types, but photographs using this technology were not available. The photographs for 1993 were of highest quality because they were in color and at a small scale (1:6,000). In some instances (1937, Fresno County; 1957, Merced County) institutions were not able to lend photographs, and high-quality photocopies of the photographs were used. Although they were considered adequate for this project, the aerial photographs used for 1978 were the least suitable because of their large scale; differences between riparian forest types based on the 1978 photographs are somewhat unreliable and should be interpreted with caution. When sufficient overlap existed between photographs, stereo pairs were examined using a Lietz MS-27 3X-magnifying stereoscope. A 6X-magnifying hand lens was also used to aid in the identification of signatures.

Table 3
Aerial Photographs Used for Historical Vegetation Mapping

Period	Date	Scale	B/W or Color	Flown for	Contact for Originals	Prints/ Photocopies	River Miles	Description
1937	9/9/1938	1:10,000 (1"=833')	B/W	USCOE	USCOE, Sacramento, CA	prints	267–243	Friant Dam to Herndon (Hwy 99)
	10/6/1937	1:7,920 (1"=660')	B/W	USDA	California State University, Fresno, Map Library, Fresno, CA	photocopies	243–175	Herndon (Hwy 99) to Merced/Fresno county line (near Hwy 152)
	7-10/1937	1:7,920 (1"=660')	B/W	USDA	Central California Irrigation District, Los Banos, CA	prints	205–136	Mendota Dam to upstream of confluence with Bear Creek
	7-8/1938	1:7,920 (1"=660')	B/W	USDA	National Archives, Washington, D.C.	prints	175–118	Merced/Fresno county line (near Hwy 152) to confluence with Merced River
1957	8/31/1957	1:12,000 (1"=1000')	B/W	USDA	Department of Water Resources, Fresno, CA	prints	267–205	Friant Dam to upstream of Mendota Dam
	7/1961	1:7,920 (1"=660')	B/W	USDA	California State University, Fresno, Map Library, Fresno, CA	photocopies	205–175	Mendota Dam to Merced/Fresno county line (Hwy 152)

Table 3 continued

Period	Date	Scale	B/W or Color	Flown for	Contact for Originals	Prints/ Photocopies	River Miles	Description
	4&5/1957	1:7,920 (1"=660')	B/W	USDA	Merced Community College, Merced, CA	photocopies	175–118 (89% of area)	Merced/Fresno county line (Hwy 152) to confluence with Merced River
	8/31/1957	1:63,360 (1"=1 mile)	B/W	USDA	USBR, Fresno, CA	prints	175–118 (ll% of area)	Merced/Fresno county line (Hwy 152) to confluence with Merced River
1978	3/8/1980	1:12,000 (1"=1000')	B/W	USDA	Department of Water Resources, Sacramento, CA	prints	267–237	Friant Dam to Biola
	12/6/1978	1:24,000 (1"=2000')	B/W	USCOE	USCOE, Sacramento, CA	prints	237–118	Biola to confluence with Merced River
1993	5/23/1993	1:6000 (1"=500')	Color	USBR	USBR, Sacramento, CA	prints	267–118	Friant Dam to confluence with Merced River

For 1937, 1957, and 1978, aerial photographs for the entire study area could not be obtained. Missing portions were filled in using photographs taken no more than four years before or after the pertinent date. The 1957 photographs were supplemented with 1961 photographs for the reach from Mendota Dam to Highway 152 (RM 175-RM 205; Table 3). The 1978 photographs were supplemented with 1980 photographs for the reach from Biola to Friant Dam (RM 237-RM 267; Table 3). Throughout this report, the year that predominantly provided the photographs is used to indicate the point in time in the analysis. For example, although photographs from both 1978 and 1980 were used to represent the third period, this period is given as "1978".

In some cases, the aerial photograph coverage did not show the entire width of the study area. The photographs always included the riparian corridor but did not always include adjacent areas. These areas, which consisted almost exclusively of agricultural land use types or grasslands, were attributed with a "no data" label on the maps.

Topographic Base Maps

Riparian habitat and land use types were transferred by hand to rectified base maps. Three types of rectified base maps were used: black-and-white photocopies of 1920s USGS topographic maps (scale = 1:31,680; surveyed: 1915-1922), current USGS 7.5-minute topographic quadrangle maps (scale = 1:24,000; surveyed: 1956 - 1965, updated 1964 - 1987), and 1976-1978 USGS "orthophoto quads" (rectified composites of aerial photographs; scale = 1:24,000). The three types of maps have different advantages: The channel planform on the 1920s topographic maps more closely resembles the 1937 conditions than the current topographic maps; the orthophoto quads most clearly represent vegetation from 1976-1978; and the current topographic maps show elevation and, in some cases, urban and industrial development through the 1980s.

The 1920s maps were used for mapping the 1937 habitat and land use types. The orthophoto quads were used for mapping the 1978 habitat and land use types from the Mendota Dam quadrangle (RM 218.5) to the Merced River. USGS does not have orthophoto quads for the area east of the Mendota Dam quadrangle, so that area was mapped on current topographic maps. With the exception of the Gustine and Stevinson quadrangle areas (downstream from RM 140) for 1993, which were mapped on orthophoto quads, the 1957 and 1993 habitat types were mapped on current topographic maps, The lower reach of the study area for 1993 was mapped on orthophoto quads for two reasons: (l) to increase consistency with the 1978 maps, and (2) because an accurate representation of streams is more important than elevation.

Mapping Precision

Riparian habitat types were mapped using a minimum mapping unit of 5 acres, and adjacent land uses were mapped using a minimum mapping unit of 20 acres. Linear features were mapped with a minimum width of 75 feet on the 1920s topographic maps and with a minimum width of 50 feet on the current topographic maps. When widths on the 1920s maps were from 75 to 250 feet and many adjacent features were also narrow and linear, the features were mapped as a line with the width indicated; this line was later expanded to a polygon with the appropriate width. On the current topographic maps, this

mapping method was sometimes used for narrow linear features (50 to 150 feet wide). The location of habitat polygons was generally more precisely mapped on the orthophoto quads than on the topographic maps because vegetation boundaries were visible on the orthophoto quads but were generally not visible on the topographic maps. Polygon location was more accurately mapped on the current topographic maps than on the 1920s maps because of the larger scale of the 1920s maps.

Mapping Accuracy

The level of accuracy in identifying the appropriate habitat type for a riparian vegetation polygon depended on the scale of the aerial photographs, the resolution of the photographs, and whether the photographs were in color or were black and white. The attribution accuracy was highest for the 1993 color aerial photographs (scale = 1:6,000) and lowest for the 1980 black-and-white photographs (scale = 1:12,000). Two small areas (6.5 river miles, or 4% of the study area) for 1957 were mapped from index composite photographic sheets at a scale of 1:63,360 (1" = 1 mile) because no coverage for these areas could be located. It is not expected that acreage estimates were seriously affected by this lower accuracy because the areas were small.

Some ground truthing of the 1993 vegetation-type attribution was performed on October 29, 1997. The ground truthing consisted of visiting mapped areas between Mendota and Firebaugh to verify aerial photograph signatures using the 1993 aerial photographs.

Because mapping precision and accuracy depended on a number of unknown and variable relationships between the created maps and aerial photographs of varying quality and scale and because ground truthing of historic vegetation was not possible, it was not feasible to quantify a confidence interval for acreages obtained from the vegetation maps; it was, therefore, also not feasible to provide even an approximate statistical significance level for the changes in acreages between years.

Riparian Habitat and Land Use Classification

Riparian habitat and land use types mapped as a part of this project are described below. Vegetation types are adapted from Holland's (1986) "Preliminary Descriptions of the Terrestrial Vegetation of California". Table 4 shows the hierarchical classification system and the method used to attribute the types in the GIS database. For riparian scrub and forest, a low-density modifier was used when the shrub or tree cover was below 30% for the polygon.

Open Water

Description of Cover Type. Open water is characterized by unvegetated permanent or semi-permanent ponded or flowing water. Open water may be the result of constructed impoundments or naturally occurring water bodies. The open water mapping category also may include small areas of riparian scrub or herbaceous riparian vegetation that were too small to map as separate polygons.

Table 4
Hierarchical Classification System for Riparian Habitat and Land Use Types

Riparian Habitat

- Open water (1000)*
- Riverwash (2000)
- Riparian vegetation (3000)
  - Riparian forest (3100)
    - Great valley cottonwood riparian forest (3110)**
    - Great valley mixed riparian forest (3120)**
    - Great valley valley oak riparian forest (3130)**
  - Riparian scrub (3200)
    - Great valley willow scrub (3200)**
  - Herbaceous riparian and marsh (3300)

Land Use

- Open space (4000)
  - Grassland and pasture (4100)
  - Agricultural field (4200)
  - Orchard and vineyard (4300)
  - Disturbed land (4400)
    - Former aggregate mining (4410)
- Urban and industrial (5000)
  - Aggregate mining (5100)
  - Other industrial (5200)
  - Urban/residential (5300)

Notes:

* The four digit codes given in parentheses are GIS codes; for riparian forest and scrub, the last digit indicates density: 0 = high density, 1 = less than 30% canopy cover.

** Conforms to natural communities described in Holland (1986)

Signature Identification. Open water was dark blue on color aerial photographs and dark black or grey on black-and-white photographs. In identifying open water, the rule used was to include only open water areas that were in some way connected to the San Joaquin River system. Areas of artificially created open water outside the riparian corridor (i.e., sewage disposal ponds) were mapped as industrial cover types.

Riverwash

Description of Cover Type. Riverwash consists of alluvial sands and gravel associated with the active channel portion of the San Joaquin River. Generally, riverwash areas exist as sand and gravel point bars within the floodplain of the river.

Signature Identification. Riverwash was easily discernible as unvegetated areas that were bright white in black-and-white aerial photographs or light grey or yellow-grey in color aerial photographs.

Great Valley Cottonwood Riparian Forest

Description of Cover Type. Great Valley cottonwood riparian forest is a multilayered riparian forest found on the active low floodplain of the San Joaquin River. Older and decadent stands of Great Valley cottonwood riparian forest also exist in areas that were formerly active floodplains but are now isolated from frequent flooding by levees, reduced flows, or channel incision.

Pristine Great Valley cottonwood riparian forest can be thought of as having three somewhat distinct layers: overstory, midstory, and understory. The overstory is dominated by winter deciduous trees that are adapted to frequent flooding. Common dominant trees in the overstory include Fremont cottonwood (*Populus fremontii*) and Goodding's black willow (*Salix gooddingii*). California wild grape (*Vitis californica*) is a conspicuous vine found growing within the canopy of this forest. The midstory is dominated by shade-tolerant shrubs and trees, such as Oregon ash (*Fraxinus latifolia*) or California box elder (*Acer negundo* ssp. *californica*). Other shrubby species of willow (*Salix* spp.) may also be present within the midstory. The understory is dominated by native grasses and forbs, such as creeping wildrye (*Leymus triticoides*), nettle (*Urtica* sp.), and Barbara sedge (*Carex barbarae*).

Great Valley cottonwood riparian forest intergrades with Great Valley willow scrub at lower elevations near the active channel and with mixed riparian forest on higher positions on the floodplain.

Signature Identification. Great Valley cottonwood riparian forest is found along the low floodplains above the active channel. The signature of Great Valley cottonwood riparian forest was identified based on the landscape position, texture of the forest canopy, and shadows thrown by tall trees. The texture of this vegetation type is rough and undulating because various ages of trees comprise this forest type. Additionally, the canopy outline of cottonwood trees is often irregular compared to the regular circular outline of valley oak trees.

Great Valley Mixed Riparian Forest

Description of Cover Type. Great Valley mixed riparian forest is a multilayered winter-deciduous forest generally found on the intermediate terrace of the floodplain of the San Joaquin River. Under pristine conditions, this vegetation type experiences less physical disturbance from floodflows than cottonwood riparian forest. However, following the construction of Friant Dam and the resulting attenuation of flood flows, it appears that sites that would typically support cottonwood riparian forest now exhibit structure and species composition similar to mixed riparian forest.

Species dominance in mixed riparian forest depends on site conditions, such as availability of groundwater and frequency of flooding. Typical dominant trees in the overstory include Fremont cottonwood, box elder, Goodding's black willow, Oregon ash, and California sycamore (*Platanus racemosa*). Immediately along the water's edge white alder (*Alnus rhombifolia*) occurs in the upper portion of the study area. Common shrubs include red willow (*Salix laevigata*), arroyo willow (*Salix lasiolepis*), and buttonbush (*Cephalanthus occidentalis*). The understory of mixed riparian forest is similar to that of Great Valley cottonwood riparian forest.

Great Valley mixed riparian forest intergrades with Great Valley valley oak riparian forest at sites higher on the floodplain and with Great Valley cottonwood riparian forest and Great Valley willow scrub on sites closer to the active channel.

Signature Identification. Mapping methods for Great Valley mixed riparian forest were similar to those for Great Valley cottonwood riparian forest. However, the photograph signature of mixed riparian forest often exhibits a more varied texture and a more open canopy because of the diversity of tree species.

Great Valley Valley Oak Riparian

Description of Cover Type. Great Valley valley oak riparian forest is a tree-dominated habitat with an open to closed canopy. This forest type is found on the higher portions of the floodplain and is therefore exposed to less flood-related disturbance than other riparian vegetation types in the study area. Dense stands of this vegetation type were not observed in aerial photographs of the study area; however, woodland-like stands of this type were observed upstream of Herndon.

Valley oak is the dominant tree in this vegetation type; California sycamore, Oregon ash, and Fremont cottonwood are also present in small numbers. Common understory species in this vegetation type include creeping wildrye, California wild rose (*Rosa californica*), Himalaya blackberry (*Rubus procerus*), and California blackberry (*R. ursinus*).

Great Valley valley oak riparian forest intergrades with mixed riparian forest closer to the active channel and with grassland habitats on higher terraces of the San Joaquin River.

Signature Identification. Mapping methods for Great Valley valley oak riparian forest are similar to those for other riparian forest types. However, the photograph signature of valley oak riparian forest often exhibits an open structure consisting of large trees with dense circular canopies. Valley oak riparian forest was also mapped based on its position in relation to the active channel (i.e., well above the active floodplain and transitional to grassland habitats). This vegetation type was also easily identified using a magnifying stereoscope and the 1993 color aerial photographs.

Great Valley Willow Scrub

Description of Cover Type. Great Valley willow scrub is a dense assemblage of willow shrubs often found within the active floodplain of the river. Sites with willow scrub are subject to more frequent scouring flows than are sites supporting riparian forests. Willow scrub often occupies more stable sand and gravel point bars immediately above the active channel. Often, riparian scrubs are successional to riparian forest and persist only in the presence of frequent disturbance.

Dominant shrubs in Great Valley willow scrub include sandbar willow (*Salix exigua*), arroyo willow, and red willow. Occasional emergent Fremont cottonwood may also be present in Great Valley willow riparian scrub.

Initially, it was also intended that buttonbush scrub, elderberry savanna, and exotic vegetation (i.e., giant reed and tamarisk) be mapped; however, following a review of the aerial photographs available for the project, it was determined that mapping these vegetation types was not feasible.

Buttonbush scrub is present on the San Joaquin River in the study area; however, patches of this vegetation type occur primarily as small-linear features along the water's edge or as small areas of scrub within back-swamps and could not be identified on aerial photographs. Additionally, without false-color infra-red aerial photographs, it is extremely difficult to separate the signature of this vegetation type from that of Great Valley willow scrub. For these reasons, it was not possible to map areas of buttonbush scrub in the study area without conducting extensive on-ground mapping.

Elderberry savanna has not been reported along the San Joaquin River within the study area (Natural Diversity Data Base 1997) and was not discernible, even on the oldest aerial photographs (1937 and 1938). Based on site conditions where this vegetation type does occur (i.e., silty, sandy soils on high floodplains along the American and Sacramento Rivers and along the San Joaquin River at Caswell State Park), it is unlikely that extensive areas of this vegetation type occurred historically along the San Joaquin River within the study area.

Exotic vegetation (i.e., giant reed and tamarisk) is present along the San Joaquin River in the study area; however, patches were too small (i.e., less than 5 acres) to be accurately mapped for this study.

Signature Identification. Great Valley willow scrub signatures on aerial photographs were identified based on landscape position and texture of the shrub

canopy. Riparian scrub is often found in areas that undergo a significant amount of scouring during flood events. Riparian scrub can also be found in disturbed areas that once supported riparian forest. The texture of the riparian scrub signature was generally smooth and uniform in areas that have been scoured by large floods, creating an even-aged stand of shrubs. Great Valley willow scrub usually had a smoother signature than other riparian shrub types dominated by several species. The latter signature was mapped as the general riparian scrub category.

When it was unclear whether scrub consisted mainly of willows or whether other shrub species were dominant, the signature was mapped as the more general riparian scrub category.

Herbaceous Riparian Vegetation and Marsh

Description of Cover Type. The herbaceous riparian vegetation and marsh cover type includes two distinct components: a terrestrial component composed of annual and perennial herbaceous vegetation found on mesic sites within the floodplain of the river and an aquatic component (i.e., tule and cattail marsh) dominated by emergent wetland vegetation.

Characteristic herbaceous riparian species in the study area include Bermuda grass (*Cynodon dactylon*), sunflower (*Helianthus* spp.), cocklebur (*Xanthium strumarium*), goosefoot (*Chenopodium* spp.), and beggar's tick (*Bidens frondosa*). Characteristic marsh species include bulrushes (*Scirpus* spp.) and cattails (*Typha* spp.).

Signature Identification. Herbaceous riparian vegetation and marsh signatures on black-and-white aerial photographs were smooth and dark and did not cast any discernable shadows. These vegetation types were typically located in seasonally saturated areas close to the active channel or in back swamps in old meander scars.

Grassland and Pasture

Description of Cover Type. Grassland and pasture is an herb- and grass-dominated vegetation type that is typically dominated by annual species. Generally, sites with grassland or pasture are well drained and may flood only occasionally. Most areas of grassland or pasture are above the frequently flooded zone of the San Joaquin River.

The grassland and pasture vegetation type is composed predominantly of an assemblage of non-native annual and perennial grasses and occasional non-native and native forbs.

Signature Identification. The grassland and pasture vegetation type was easily discernible in the aerial photographs because of its landscape position and signature color and texture. Signature texture of grassland and pasture was smooth and uniform throughout. Signature color was typically light because most of the aerial photographs used were taken when the majority of annual grasses had dried. Fallow fields with grassland cover that did not show recent evidence of cultivation (i.e., plow lines or irrigation ditches) were also mapped as grassland and pasture.

Orchard and Vineyard

Description of Cover Type. Orchards and vineyards are agricultural areas planted in vines or trees and used for the production of stone fruits, nuts, raisins, and table grapes.

Signature Identification. Orchards and vineyards were clearly identifiable in aerial photographs because of orderly rows of small vines or larger trees.

Disturbed Land–Other

Description of Cover Type. Land in the "disturbed land–other" cover type is land that has undergone some level of disturbance that did not appear to be related to agricultural cultivation or aggregate extraction. Common examples of the disturbed land–other category include areas used by off-highway vehicles and sites where rubble or fill has been deposited.

Signature Identification. The disturbed land–other cover type typically showed evidence of the removal of natural vegetation, with bare earth or rubble being the predominant ground cover.

Disturbed Land–Former Aggregate Mining (Inactive)

Description of Cover Type. The disturbed land–former aggregate mine cover type was mapped in areas that were formerly aggregate mines but now exist as dry or unvegetated open pits. Where former aggregate mines were vegetated or had standing open water, other cover types took precedence in the mapping; the category of formerly mined areas is, therefore, underestimated.

Signature Identification. Inactive aggregate mines were identified by the presence of open excavations lacking vegetation. Inactivity was based on the absence of mining equipment (e.g., conveyors, rail lines, and heavy equipment).

Aggregate Mining–Active

Description of Cover Type. Active aggregate mines were mapped in areas of active aggregate extraction. Open water areas within active aggregate mining operations were mapped as open water, which is described above.

Signature Identification. Active aggregate mines were identified by the presence of open-pit excavations and of mining machinery and infrastructure (e.g., conveyors, haul roads, rail lines).

Other Industrial

Description of Cover Type. The other industrial cover type was used for farm compounds and outbuildings not associated with aggregate mining.

Signature Identification. Other industrial areas consisted primarily of a number of sheds and/or buildings on larger agricultural land holdings. Many of these areas are local landmarks (i.e., Poso Farm and Turner Ranch).

Urban/Residential

Description of Cover Type. The urban/residential cover type indicates areas developed for urban land uses.

Signature Identification. Urban/residential land was easily identified based on the presence of dense buildings, houses, and roads.

Digital Data Management and Quality-Control Procedure

The hand-drawn maps were digitized using Autocad Version 12 software. The root mean square digitizing error was less than 14.7 feet. The digitized lines and attributes were exported to ARC/INFO Version 7.1 software and built into separate polygon coverages for each map. The ARC/INFO files were created as metric Universal Tansverse Mercator (UTM) zone 10 coverages. A uniform study area boundary was drawn on a set of 7.5-minute quadrangle maps and digitized, and all riparian habitat and land use data were clipped at this boundary. The soil map was intersected with this boundary so that the area of riparian soils inside and outside the study area could be quantified.

Acetate overlays with habitat and land use type polygons were printed for each hand-drawn map, and all attributes and lines of the ARC/INFO generated overlays were proofed and any errors corrected. A set of final acetate overlays for USGS 7.5-minute quadrangle maps showing riparian supporting soil and all habitat and land use maps as well as the digital data were provided to the SJRRHR Management Team.

Data Analysis and Interpretation

The habitat and land use maps and soil maps were intersected with the study reaches in ARC/INFO, and acreages of riparian soils and habitat and land use were calculated by reach. For each reach, an interpretation was developed of the changes in riparian habitat types over time as a function of known changes in land use and hydrology. As in most historical analysis, it was not always possible to assign exact, unambiguous causes to the observed historical changes. However, factors that are likely to be the cause of a number of historical patterns of changes in riparian vegetation could be identified. These factors should be considered in future restoration plans.

In addition to maps showing acreage changes, maps of a typical subreach of each study reach were produced, showing habitat and land use change and riparian soils. For

each of these reaches, a typical schematic vegetation cross section was generated for 1937 and 1993. The cross sections were taken at locations for which 1914-1915 elevational cross sections existed (U.S. Army Corps of Engineers 1917). These map figures and cross sections are presented to illustrate the spatial patterns of vegetation change. Areas outside the typical subreaches were compared between years using maps at a scale of 1:24,000 and Arcview 3.0 software; these maps have been provided to the SJRRHRP Management Team, but are not displayed in this report.